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# Art. XVI.—*Australian and New Zealand Species of the Foraminiferal Genera* Operculina *and* Operculinella.

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## Introduction.

The present paper is the outcome of a study undertaken for the purpose of arriving at a proper understanding of the species of *Operculina*, fossil and Recent, occurring in Australia and New Zealand. The genus *Operculinella* has been included in view of the very close relationship it bears to *Operculina*.

As far back as 1932 the present authors read a paper before the Australian and New Zealand Association for the Advancement of Science in Sydney, entitled "The Revision of the East Indian and Australian Species of Operculina", but which was then only published in abstract. The following paper is an enlargement of the subject, considerably extended and brought to date.

Consideration has been given to the following forms, which, so far as we have been able to ascertain, comprise those recorded from the Indo-Pacific region as *Operculina* or *Operculinella*, or appearing to belong to either genus. The reference given in each case is to the original author, whether the species or variety was or was not described from this area.

1781. *Nautilus ammonoides* Gronovius, p. 282, No. 1220, pl. xix. (Fasc. iii., Tab. 2), figs. 5, 6. Recent, Bay of Bengal.

1798. *Nautilus radiatus* Fichtel and Moll, p. 58, pl. viii., figs. *a-d*. Recent, Red Sea.

1798. *Nautilus venosus* Fichtel and Moll, p. 59, pl. viii., figs. *e-h*. Recent, Red Sea.

1822. *Lenticulites complanata* Defrance, Dict. Sci. Nat., vol. xxv., p. 453. Miocene, Dax, France.

1826. *Operculina madagascarensis* d'Orbigny, p. 281, No. 4. Recent, Madagascar.

1826. *O. gaimardi* d'Orbigny, p. 281, No. 5. Recent, Rawack.

1826. *Assilina discoidalis* d'Orbigny, p. 296, No. 1, Modèles, No. 88. Recent, Rawack.

1826. *A. nitida* d'Orbigny, p. 296, No. 4. Recent, Red Sea.

1839. *Planulina pyramidum* Ehrenberg, p. 133. Eocene, Egypt.

1846. *Operculina granulosa* Leymerie, p. 359, pl. xiii., fig. 12. Eocene, near Corbières, Southern France.

1850. *O. canalifera* d'Archiac, p. 245. Eocene, France.

1859. *Amphistegina cumingii* Carpenter, p. 32, pl. v., figs. 13-17. Recent, China Sea.

1896. *Operculina granulosa*, var. *niasi* Verbeek, p. 1158, pl. ix., figs. 128-131. Eocene, Island of Nias.

1896. *O. javana* Verbeek, p. 1159, pl. ix., figs. 132, 133. Upper Tertiary of Java.

1921. *O. bartschi* Cushman, p. 376, text-fig. 13. Recent, Philippines.

1921. *O. bartschi,* var. *plana* Cushman, p. 377, text-fig. 14. Recent, Philippines.

1921. *O. ornata* Cushman, p. 378, pl. lxxiv., figs. 2*a*, *b*. Recent, Philippines.

1921. *O. philippinensis* Cushman, p. 379, text-fig. 15. Recent, Philippines.

1921. *O. discoidalis,* var. *involuta* Cushman, p. 380, text-fig. 16. Recent, Philippines.

1921. *O. elegans* Cushman, p. 381, pl. xcvii., fig. 3. Recent, Philippines.

1925. *O. bartschi,* var. *punctata* Yabe and Hanzawa, p. 52, pl. vi., figs. 13-15; pl. vii., figs. 15-18. Late Tertiary and Post-Tertiary of Riukiu Islands.

1930. *O. complanata,* var. *multiseptata* Yabe and Hanzawa, p. 39, pl. ii., figs. 6, 7, 10; pl. xv.; pl. xvi., fig. 1. Middle Miocene, Taiwan (Formosa).

1932. *O. pacifica* Whipple, p. 83, pl. xx., figs. 1, 8. Eocene, Eua, Tonga.

1933. *O. heterosteginoides* Hofker, p. 148, pl. vi., figs. 1, 2; text-fig. 33. Recent, Kei Archipelago.

Because of the difficulty of distinguishing whether the differences between specimens of *Operculina* are specific or merely due to conditions of environment or to dimorphism or trimorphism, the genus is in a very unsatisfactory condition. Hofker, who has studied the Recent East Indian *Operculinae* from a biological standpoint, considers that all of the species recorded from this area (except *O. heterosteginoides*) should be placed under *O. complanata* (Defrance). He regards the differences as due to trimorphism and conditions of environment. In view of the importance placed by Hofker on the relation of the size of the proloculus to the external characters of the test, it will be of interest to summarise his views on this and to consider under each species how far they are supported by the material we have examined. He gives (Hofker, 1927, p. 61) the characteristics of the three forms thus:—

"*Forma A*1.—Sutures never with well developed buds of secondary chalk (only the central part of the shell shows some heaps of clear chalk-material), and very little chalk buds on the chamber walls. Proloculum about 35 microns; marginal cord not very distinguishable in the more involute speciments. Chambers very numerous, especially in flat individuals.

*Forma B*.—Always very large specimens (up to 9 mm. diameter) with smooths walls, ornamented with very small chalk buds. Only the centre of the shell with chalk masses on the sutures. Chambers very numerous. Proloculum 27 microns.

*Forma A2.*—Sutures with very well developed buds of secondary chalk and with very large masses of chalk material on the walls. Most individuals are very strongly built, with somewhat rounded chambers, the number of which is mostly a little smaller. Proloculum about 60 microns."

Before proceeding further, it is proposed to give an account of *Operculina complanata*, as it occurs in the vicinity of Bordeaux, France, from whence it was described, after which a list of the species we have recognised, followed by notes on each, will be given.

## Operculina complanata (Defrance).

(Plate XVI., figs. 1, 2, text fig. 1.)

*Lenticulites complanata* Defrance, 1822, Dict. Sci. Nat., vol. xxv., p. 453.

*Operculina complanata* (Defr.): d'Orbigny, 1826, p. 281, pl. xiv., figs. 7-10; Modèles, No. 80.

This species was described from the Lower Miocene (Aquitanian) of Dax, near Bordeaux, France. We have examined suites of specimens from this locality and from beds of similar age in the same area, viz., from Saucat and Lagus. From these the following description of *O. complanata* is given:—

Test ear-shaped, with a rounded peripheral keel (the "marginal cord"), strongly compressed and with both faces slightly concave, not thickened in the centre; chambers numerous, in up to $3\frac{1}{2}$ whorls in the megalospheric form, increasing gradually in size as added, but always very narrow, numbering 25 or more in the last-formed whorl; sutures thin and evenly recurved, not limbate or raised, barely visible from the exterior. Major diameter of test, 8 mm., minor diameter, 6 mm.

In exterior view, the surface of all of our specimens is smooth, except those from Lagus, which, particularly when moistened, show a faint irregular beading on the interseptal areas. In thin section, however, the Dax examples show traces of beading on the chamber surface. The Lagus specimens are thinner shelled and appear to have come from a less-calcareous deposit than those from Dax and Saucat. The specimens are all megalospheric, the proloculus averaging 0.18 mm. in diameter (external measurement).

The most striking feature of *O. complanata* is one to which reference does not appear previously to have been made. This is the remarkable development of the interseptal canal system on the anterior side of each chamber. The interseptal canals form at regular intervals short branches which extend forward and outward under the chamber wall, where they appear to terminate blindly. The shell material enclosing these branches, when seen in a thin section of the test, gives the effect of a series of brackets on the septum, supporting the outside chamber wall. This structure is illustrated in Figs. 1 and 2 on Plate XVI., and has also been figured by Silvestri (1907, pl. ii., fig. 4), who, however, apparently was not aware that it was characteristic of *O. complanata* and accordingly recorded his specimens under the name of *O. complanata*, var. *heterostegina*, var. n. His material was from Northern Italy, from beds of the same age as those from which *O. complanata* was described.

This structure was not recorded or figured by Hofker in connection with the Siboga material referred by him to *O. complanata* and we are therefore unable to agree with his identification of the East Indian Operculines with Defrance's species. It may be noted that Hofker has since recognised a similar structure in material collected by Dr. Th. Mortensen's Pacific Expedition 1914-16 and has, on it, based a new species *O. heterosteginoides* (Hofker, 1933, p. 148, pl. vi., figs. 1, 2; text-fig. 33). He mentions that this species has been described in some records as only a variety of *O. bartschi* Cushman and also that it did not occur in the Siboga material.

The only other species showing the same structure as *O. complanata*, which has been described from the Indo-Pacific region, is *O. pacifica* (Whipple, 1932, p. 83, pl. xx., figs. 1, 8) from the Eocene, of Eua, Tonga.

*O. complanata* accordingly shows a more advanced development than most of the Indo-Pacific species of *Operculina* and therefore connects the simpler forms of the genus with *Heterostegina*. It may be mentioned that the senior author, in 1900 (Chapman, 1900, p. 18, pl. iii., fig. 6), showed that, in the microspheric form of *Heterostegina depressa* d'Orb., the first few chambers are undivided and are immediately followed by several chambers with rudimentary septation, as in *Operculina complanata*. The next stage in the division of the chambers is the presence of incomplete cross septa which do not extend more than two-thirds across the chamber cavity, after which the characteristic secondary septation of *Heterostegina* is taken on.

## List of Species Recognized.

Eocene:

*Operculina pyramidum* (Ehrenberg)
*O. canalifera* d'Archiac.

Miocene:

*O. victoriensis,* sp. nov.
*O. kawakawaensis,* sp. nov.
*O. matapauensis,* sp. nov.

Recent:

*O. ammonoides* (Gronovius).
*O. bartschi* Cushman.
*Operculinella venosa* (Fichtel and Moll).

## Acknowledgments.

We are indebted to Mr. Arthur Earland, F.R.M.S., and to Dr. J. A. Cushman for information concerning *Operculina ammonoides* from the rare work of Gronovius. Mr. Earland has also kindly supplied us with a number of examples of *Operculinae* from the Indian Ocean. We wish also to extend our best thanks to Professor J. H. F. Umbgrove, of Delft University, for homoetypes of *O. javana* Verbeek.

## Description of the Species.

Genus **Operculina** d'Orbigny, 1826.

*Eocene Species.*

OPERCULINA PYRAMIDUM (Ehrenberg).

*Planulina pyramidum* Ehrenberg, 1839, p. 133.
*Operculina pyramidum* (Ehr.): Schwager, 1883, p. 143, pl. xxix., figs. 4*a-c*. Chapman and Crespin, 1935, p. 59.

This species was recorded by Chapman and Crespin (*loc. cit.*) as occurring in sections of limestone from near Bullara, North-west Division, Western Australia, in association with *Discocyclina*. The sections have not been available for re-examination and figuring.

OPERCULINA CANALIFERA d'Archiac.

*Operculina canalifera* d'Archiac, 1850, p. 245. Chapman and Crespin, 1935, p. 59.

The comments made in relation to the preceding species apply also to this.

*Miocene Species.*

OPERCULINA VICTORIENSIS, sp. nov.

(Plate XVI., figs. 3-8, text-fig. 2.)

*Operculina complanata* Chapman (*non Lenticulites complanata* Defrance), 1910, p. 294.
*O. complanata*, var. *granulosa* Chapman (*non O. granulosa* Leymerie), 1910, p. 294.
*O. bartschi* Crespin (*non* Cushman), 1936, pl. i., fig. 12.

Test ovate, compressed, complanate, sometimes with the faces slightly concave, with a narrow peripheral keel; chambers numerous, in up to $3\frac{1}{4}$ whorls in the megalospheric form, number in last-formed whorl averaging 16-18; sutures usually limbate and raised, radial at inner end and with outer end sharply reflexed, sometimes evenly reflexed throughout. Larger diameter of megalospheric specimens up to 4 mm.; microspheric specimens up to 6 mm.

Holotype (Chapman Coll.) from Lower Miocene, Red Bluff, Shelford, Vic.

This species is of common occurrence in Miocene deposits in Victoria, being found in limestones and marls. To show what relationship, if any, exists between the external characters of the shell and the size of the proloculus, the following notes on the specimens occurring in a typical series of samples are given :—

Mines Department Bore, Parish of Nuntin, at 190 feet. Lower Miocene—B 2 Zone.

Apparently a moderately deep water deposit. *Cycloclypeus communis* Martin is common and the specimens thin-shelled and almost transparent.

28 specimens of *Operculina* were examined. These fall into two groups—

(1) Sutures limbate, raised and more or less beaded. Chamber walls ornamented with beads, which vary from a single row of comparatively large sized beads along the centre of the chamber to smaller beads closely covering the surface of the chamber. Most specimens show chamber beading of an intermediate type.—25 specimens.

(2) Practically smooth specimens, with a few beads on the early sutures.—3 specimens.

Specimens of both forms attain a diameter of 3 mm. The number of whorls in each does not exceed $3\frac{1}{2}$, with 15 to 17 chambers in the outside whorl. The average height of the chambers in the last quarter whorl is 0.3 mm. The proloculus in both forms measures between 0.04 and 0.05 mm. in diameter.

Geological Survey Bore, Hamilton, 80-85 feet. Lower Miocene—B 2 Zone.

Material a richly foraminiferal marl, with abundant *Lepidocyclinae* and *Amphisteginae*. It is apparently a shallower water deposit than the preceding.

23 specimens were examined. These fall into the following groups—

(1) Sutures limbate and raised, with beading usually best developed on sutures of earlier chambers. Few large beads on centre of shell. Chamber walls ornamented—(*a*) along centre with few comparatively large beads; (*b*) whole surface closely beaded; and (*c*) intermediate beading.—18 specimens.

(2) Sutures limbate, sometimes much raised. Chamber wall smooth.—5 specimens.

Particulars of specimens sectioned are as follows:—

| Specimen Number— | 1. | 2. | 3. | 4. | 5. |
|---|---|---|---|---|---|
| Larger diameter .. | 2·6 mm. (estimated) | 3 mm. (estimated) | 2·9 mm. | 3 mm. | 2·8 mm. |
| Diameter of proloculus (external and internal) | 0·112; 0·079 mm. | 0·102; 0·060 mm. | 0·115; 0·086 mm. | 0·109; 0·068 mm. | 0·05; 0·029 mm. |
| Number of whorls .. | 3 | 3½ | 3½ | 3 | 4 |
| Number of chambers in outside whorl | 17 | 16 | 13 | 17 | 17 |
| Aver. width of chambers in last ¼ whorl | 0·29 mm. | 0·3 mm. | 0·23 mm. | 0·36 mm. | 0·2 mm. |
| Sutures .. .. | Limbate and raised | Limbate and beaded | Limbate, much raised | Limbate, little raised | Limbate, slightly raised |
| Ornament on chamber walls | Few, fairly strong beads in centre of chamber | Covered with medium sized beads | Wall smooth | Wall smooth | Wall smooth |

These specimens show that, in the Hamilton Bore at least, the smooth-shelled form is not necessarily the microspheric and that the A form may be either smooth-shelled or beaded on both sutures and chamber walls.

## Red Bluff, Shelford.

Lower Miocene.—Stratigraphic position unsettled, but younger than the two preceding—probably of the same age as Balcombe Bay beds.

Material a yellow marl, apparently formed in fairly deep water, and rich in foraminifera. *Operculina* very common and the only large foraminifer present. 110 specimens were examined. These fall into three groups—

(1) Very finely beaded all over.—2 specimens.

(2) Very slightly beaded in early portion of shell.—75 specimens.

(3) Wholly smooth.—33 specimens.

The sutures are limbate and very slightly raised in all cases.

Particulars of the specimens sectioned are as follows:—

| No. | Larger Diameter of Shell. | Diameter of Proloculus (External and Internal). | No. of Whorls. | Chambers in Last Whorl. | Average Width last ¼ Whorl. | Sutures. | Ornament on Chamber Walls. |
|---|---|---|---|---|---|---|---|
| 1 | 3·2 mm. | 0·137; 0·078 mm. | 3½ | 16 | 0·34 mm. | Limbate, raised | Covered with small beads |
| 2 | 2·8 mm. | 0·114; 0·078 mm. | 3 | 15 | 0·3 mm. | ,, | Few small beads on early chambers |
| 3 | 3·4 mm. | 0·115; 0·070 mm. | 3⅝ | 20 | 0·3 mm. | Thick limbate, raised | ,, ,, |
| 4 | 2·9 mm. | 0·124; 0·072 mm. | 3½ | 16 | 0·2 mm. | Limbate raised and very sharply reflexed | Nil |
| 5 | 3·1 mm. | 0·116; 0·080 mm. | 3 | 17 | 0·2 mm. | Limbate raised | Few large beads on centre of each side of test |
| 6 | 3 mm. | 0·112; 0·081 mm. | 3½ | 19 | 0·2 mm. | ,, ,, | ,, ,, |
| 7 | 3·4 mm. | 0·054; 0·030 mm. | 4 | 20 | 0·3 mm. | Limbate barely raised | Nil |
| 8 | 3·6 mm. | 0·160; 0·105 mm. | 3¼ | 19 | 0·3 mm. | ,, ,, | Nil |

Trimorphism therefore appears to be present in the Red Bluff specimens, Nos. 1, 2, 3, 4, 5, and 6 representing the A1 form, No. 8 the A2, and No. 7 the B. The external characters of the test are not, however, consistent with the size of the proloculus

## Flinders.

### Lower Miocene—B 2 Zone.

Polyzoal limestone, with *Lepidocyclina*, *Amphistegina*, *Hofkerina*, *Operculina*, etc. The calcareous foraminifera are all thick-shelled.

27 specimens of *Operculina* were examined. These fall into the same two groups as the Nuntin Bore specimens—

Group 1. 23 specimens.

Group 2. 4 specimens.

Details of three specimens examined in section are as follows:—

| Specimen Number— | 1. | 2. | 3. |
|---|---|---|---|
| Larger diameter .. | 2·4 mm. | 2·1 mm. | 2·3 mm. |
| Diameter of proloculus (external and internal) | 0·090; 0·053 mm. | 0·118; 0·068 mm. | 0·160; 0·083 mm. |
| Number of whorls .. | 3 | 2¾ | 2¾ |
| Number of chambers in last whorl | 14 | 20 | 15 |
| Average width of chambers in last ¼ whorl | 0·24 mm. | 0·2 mm. | 0·2 mm. |
| Sutures .. .. | Raised and beaded | Limbate and much raised | Slightly raised and beaded |
| Ornament on chamber walls | Surface closely covered with medium sized beads | Nil | Rows of medium sized beads along depressed chamber surface |

These are all of Form A, although three types of ornament are represented and Specimen No. 2 has a considerably larger number of chambers to the outside whorl than the other specimens.

The genus *Operculina* is very common in the Lower Miocene of the old Altona Bay Coal Shaft. Except as regards size, the specimens exhibit the same lack of relationship beween the size of the proloculus and the external characters of the shell. Sections of two specimens of the A form show the proloculus to have the following dimensions:—

External diameter—(1) 0.115 mm.; (2) 0.113 mm.

Internal diameter—(1) 0.082 mm.; (2) 0.069 mm.

Similar details in regard to a microspheric specimen 5 mm. in diameter are—0.036 (external) and 0.026 (internal). This has five whorls, with 20 chambers in the outside whorl. The A form has up to $3\frac{1}{2}$ whorls, with a maximum of 20 chambers in the last-formed whorl.

The species showing the closest affinity with *O. victoriensis* is probably the Recent *O. bartschi* Cushman, described from the Philippines. The latter species is considerably larger, attaining a diameter of 8 mm. and it has 20 to 25 chambers to the whorl, as compared with a maximum of 20 in *O. victoriensis*. The central portion of the shell is often much thickened and strongly biconvex, while this is never seen in *O. victoriensis*.

Distribution:—Victoria—Railway Cutting, Neumerella; Skinner's, Mitchell River, Bairnsdale; Shell lime pit, E. of Longford; Robinson's Quarry (Dutson's), Longford; Flinders; Balcombe Bay, Mornington; Altona Bay Coal Shaft; Green Gully, Keilor; marl beds in polyzoal limestone, north end of Bathing Beach, Torquay; Filter and Upper Quarries, Batesford; Campbell's Point, Lake Connewarre; Red Bluff, Shelford; Muddy Creek, Hamilton; Portland.

South Australia—Cliffs on Murray River, near Morgan.

The above records are all from surface exposures. The species is also common in borings in Gippsland, Western Victoria, and the Mallee. The range of *O. victoriensis* appears to extend from the upper part of the Lower Miocene to the Middle Miocene.

OPERCULINA KAWAKAWAENSIS, sp. nov.

(Plate XVI., fig. 9; text-fig. 3.)

*Operculina complanata* Chapman (*non Lenticulites complanata* Defrance), 1926, p. 91, pl. xviii., fig. 1; pl. xix., fig. 3.

Test ovate, compressed, with a strong peripheral keel which forms a raised margin to both faces of the test; central portion of each face flat, the outside whorl with the lateral surfaces slightly concave; whorls numbering up to $2\frac{3}{4}$; chambers numerous, 22-23 in the adult whorl, each about six times as long as wide; sutures broad, limbate, much raised in the outside whorl, and evenly recurved. Larger diameter of the test up to 4 mm.; lesser diameter up to $3\frac{1}{2}$ mm.

Holotype in Auckland University Museum Coll.

This species occurs in great numbers in a rock-specimen kindly loaned to us by Professor J. A. Bartrum from the Auckland University Collection. The material is a firmly-consolidated greensand from the dumps of one of the old coal mines at Kawakawa, Bay of Islands, New Zealand. For full details of the occurrence of this rock, reference should be made to the senior author's notes in the paper quoted above.

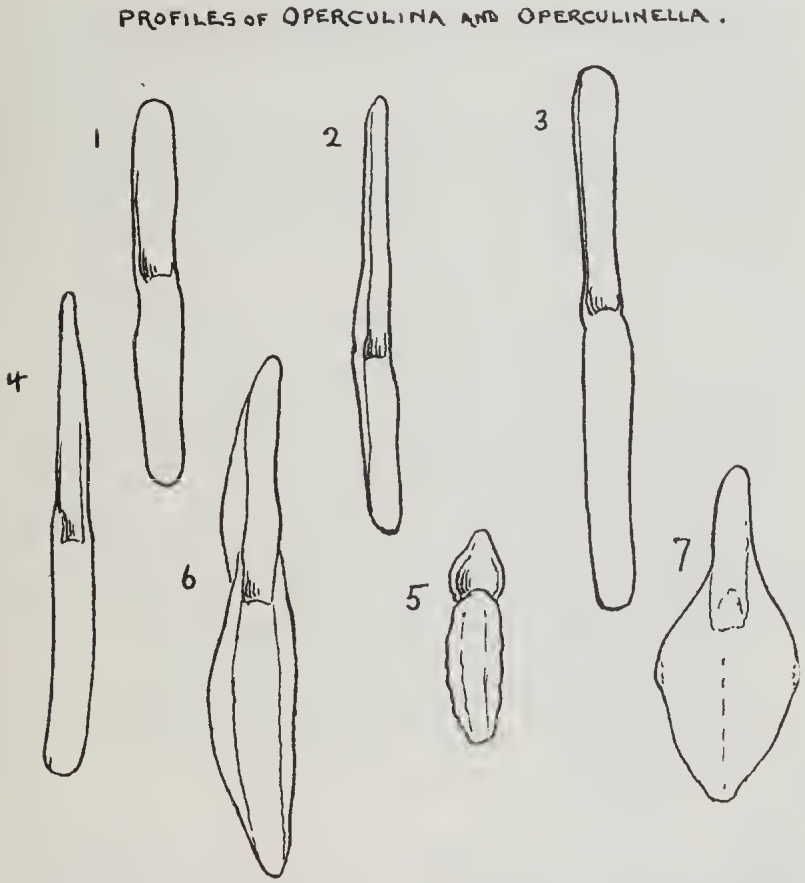
*O. kawakawaensis* bears a good deal of resemblance to *O. complanata*, particularly in the shape of the chambers and the number of chambers to a whorl. Sections made show, however, that the septal processes found in *O. complanata* are not present in the New Zealand species, which may also be distinguished by the very strong, flat-topped, protuberant sutures.

The only specimens are from the Lower Miocene of Kawakawa where it is found associated with an undescribed species of *Halkyardia*.

OPERCULINA MATAPAUENSIS, sp. nov.

(Plate XVII., figs. 10, 11; text-fig. 4.)

Test almost circular to ovate, compressed, complanate, with a very broad peripheral keel, which forms a raised rim to both faces of the test and frequently to the earlier whorls; whorls as many as $4\frac{1}{4}$ in the A form; chambers numerous, 4 to 5 times as long as wide in the last quarter whorl, up to 22 in the last whorl; sutures strongly recurved, usually limbate and raised; surface of chambers slightly depressed, sometimes with a few, fairly large beads irregularly placed on the surface of the earlier chambers. Diameter up to 3.3 mm.




TEXT-FIG. 1.—1. *Operculina complanata* (Defr.). Plesiotype. L. Miocene (Aquit.), Dax, France. × 12. 2. *O. victoriensis*, sp. nov. Holotype. L. Miocene, Shelford, Vic. × 14. 3. *O. kawakawaensis*, sp. nov. L. Miocene, Kawakawa, Bay of Islands, N.Z. From section of specimen on rock surface. × 16. 4. *O. matapauensis*, sp. nov. Holotype. Miocene, Matapau, New Guinea. × 16. 5. *O. ammonoides* (Gron.). Plesiotype. Great Barrier Reef, near Townsville, Queensland. × 12. 6. *O. bartschi* Cushman. Form A. Plesiotype. Off Masthead Island, Queensland, 20 fms. × 12. 7. *Operculinella venosa* (F. and M.). Plesiotype. Shark Bay, W.A. × 12.

Holotype (Chapman Coll.) from Miocene of Matapau, New Guinea.

This species is common at Matapau, where it occurs in association with *Calcarina defrancii, Baculogypsina sphaerulata, Elphidium craticulatum, Ammomassilina alveoliniformis,* and other forms of a Recent, tropical, shallow-water aspect. It is not likely to be mistaken for any previously-described form.

What appear to be the A and B forms were found. A section of the former shows a thick marginal cord following the spiral suture, $4\frac{1}{2}$ whorls, with 22 chambers in the outside whorl, and

a proloculus measuring 0.058 mm. in internal diameter (external, 0.073 mm.). The marginal cord is much narrower in the section of the other form. This specimen has four whorls, with 16 chambers in the outside whorl. The proloculus is 0.026 mm. in internal diameter (external, 0.055 mm.). The shell wall of both specimens is smooth and the sutures are limbate and raised.

The only specimens of *O. matapauensis* are from the type locality, where it is common.

### *Recent Species.*

### Operculina ammonoides (Gronovius).

(Plate XVII., figs. 12-16, text-fig. 5.)

*Nautilus ammonoides* Gronovius, 1781, p. 282, pl. xix., figs. 5, 6.
*Assilina discoidalis* d'Orbigny, 1826, p. 296, No. 1, Modèles, No. 88.
*Operculina gaimardi* d'Orb., 1826, p. 281, No. 5.
*Assilina nitida* d'Orb., 1826, p. 296, No. 4.
*Operculina gaimardi* d'Orb.: Fornasini, 1903, p. 396, pl. xiv., fig. 4.
*Assilina discoidalis* d'Orb. var.: Fornasini, 1903, p. 396, pl. xiv., fig. 8.
*A. nitida* d'Orb.; Fornasini, 1903, p. 397, pl. xiv., fig. 11.
*Operculina discoidalis* (d'Orb.): Cushman, 1921, p. 379.
*O. discoidalis*, var. *involuta* Cushman, 1921, p. 380, text-fig. 16.
*O. elegans* Cushman, 1921, p. 381, pl. xcvii., fig. 3.
*O. ammonoides* (Gron.): Cushman, 1921, p. 382.
*O. gaimardi* d'Orb.: Cushman, 1924, p. 50, pl. xvii., fig. 4.
*O.* (*Operculinella*) *venosa* Yabe and Hanzawa (*non Nautilus venosus* Fichtel and Moll), 1925, p. 49, pl. v.; pl. vi., figs. 1-5; pl. viii., figs. 1-10.
*O. complanata* Hofker (*non Lenticulites complanata* Defrance), 1927 (pars), p. 61.

This is a very variable species, within well-defined limits. The test is, as a rule, rounded in outline and biconvex, with a peripheral keel. The thickness of the test varies considerably, the extremes being represented by d'Orbigny's Modèle of *Assilina discoidalis* and his figure, as reproduced from his Planche Inédite by Fornasini, of *A. nitida*. The chambers are numerous, increasing fairly slowly in size as added. They may number as many as 24 in the adult whorl. The surface of the chambers may be smooth, but is frequently covered with numerous small papillae and occasionally with large clear beads.

The sutures are generally slightly recurved, the amount of curvature being greatest at the outer end. In some specimens they may be depressed, but, as a rule, they are limbate and raised, most usually strongly beaded. The limbation is occasionally very heavy and the sutural beads very large, three or four beads making up the length of the suture of the chamber. The position of the proloculus is generally indicated by a large bead of clear shell substance in the centre of each face.

The most striking variation is in the extent to which each whorl overlaps the preceding whorls. This has been excellently illustrated by Yabe and Hanzawa (*loc. cit.*) in series of Recent specimens from Samoa and younger Tertiary examples from the Riukiu Islands. In shape, the involute specimens resemble *Operculinella venosa,* with which they have been identified, but *O. venosa* always has the early whorls involute, and the suture lines are sinuous and not beaded, the surface of the test being plane and smooth. Reference to Fichtel and Moll's figures of *O. venosa* and to the later descriptions and figures given by Carpenter, Brady, and Hofker (vide *Operculinella venosa,* postea) will show how different the two species are.

In any large series of examples of *O. ammonoides,* specimens will be found in which the whorls widen more rapidly than in the typical form of the species, resulting in an ear-shaped, comparatively thin, test. This, in our opinion, represents d'Orbigny's *O. gaimardi,* which was first recorded from Rawack, the type locality of *O. discoidalis* d'Orb., which is undoubtedly identical with *O. ammonoides.*

*O. discoidalis,* var. *involuta,* and *O. elegans,* described by Cushman (*loc. cit.*) from the Philippines are also considered to come within the limits of variation of *O. ammonoides.*

Sections made of *O. ammonoides* show the following:—

| Specimen Number— | 1. | 2. | 3. (*O. gaimardi* form.) | 4. |
|---|---|---|---|---|
| Larger diameter .. .. | 2·1 mm. | 1·6 mm. | 2·1 mm. | 1·9 mm. |
| Diameter of proloculus (external and internal) | 0·073; 0·038 mm. | 0·054; 0·031 mm. | 0·037; 0·017 mm. | 0·079: 0·048 mm. |
| Number of whorls .. | 4 | 4 | 4 | 3 |
| Chambers in outside whorl .. | 18 | 16 | 16 | 13 |
| Average width chambers last ½ whorl | 0·2 mm. | 0·15 mm. | 0·15 mm. | 0·15 mm. |
| Sutures .. .. .. | Beaded | Early beaded, then limbate | Beaded, outer end recurved | Few, very large beads |
| Ornament on chamber walls | Nil | Finely papillate | Nil | Nil |

Specimens Nos. 1, 2, and 3 are from the Great Barrier Reef, near Townsville. No. 4 is from North-East Bay, Great Palm Island.

The types of *O. ammonoides* were from the Bay of Bengal. The species is widely distributed in shallow water in the tropical Indo-Pacific region. On the Barrier Reef, it appears to be found in shallower water than *O. bartschi.* In view of the rarity of the work of Gronovius, in which *O. ammonoides* was described, we reproduce, by the kindness of Dr. J. A. Cushman, a photograph of the type figure.

Distribution.—Recent: Numerous localities on the Great Barrier Reef, Queensland.

Post-tertiary: Bore on Michaelmas Reef, 22 miles N.E. of Cairns, Queensland, between 441 and 600 feet.

Late Tertiary: Yule Island, Papua.

### Operculina bartschi Cushman.

(Plate XVII., figs. 17-20, text-fig. 6.)

*Operculina bartschi* Cushman, 1921, p. 376, text-fig. 13.
*O. bartschi,* var. *plana* Cushman, 1921, p. 377, text-fig. 14.
*O. bartschi, var. ornata* Cushman, 1921, p. 378, pl. lxxiv., figs. *2a, b.*
*O. philippinensis* Cushman, 1921, p. 379, text-fig. 15.
*O. complanata* Hofker (*non Lenticulites complanata* Defrance), 1927 (pars), p. 61.

Cushman's description of *O. bartschi* is as follows:—

"Test comparatively large, compressed except in the central region, coils widening rapidly; central portion thickened, biconvex, composed of several coiled chambers, and ornamented on the surface with numerous comparatively large bosses; chambers numerous, 20 to 25 in the last-formed coil; curved sutures distinct, not ornamented, but the chambers between with numerous comparatively large granulations, usually in somewhat definite lines across the test. Diameter up to 8 mm."

The types were from the Philippines, in 25 fathoms.

The variety *plana* was described as having the surface of the later chambers smooth, very thin and translucent. In the variety *ornata,* the sutures are beaded and the surface of the later chambers is smooth. Cushman states that all three forms occur together. *O. philippinensis* seems to us to be another variant on *O. bartschi,* with which it is frequently associated around the Philippines.

The only examples of *O. bartschi* we have are from off Masthead Island, in the Capricorn Group, from 20 fathoms, where it is common. Three forms are present. The first attains a diameter of 6 mm. and is very strongly built. The central portion of the test is much thickened and with masses of clear shell material which obscure the early whorls. It has three whorls in the adult, with up to 22 chambers to the whorl. There is a strong marginal keel. The early sutures are beaded, those in the later part of the test being limbate and sometimes slightly raised. Occasionally all of the sutures are beaded. The surface of the chambers may be smooth, ornamented with a few large beads, or they may be covered with very small tubercles, amongst which may be irregular rows of larger beads.

The second form is smaller, with a maximum diameter of 3 mm. It has up to $4\frac{1}{2}$ whorls, with not more than 18 chambers to a whorl, but usually less. The central portion of the test

is only slightly thickened. Any beading is confined to the early sutures. The wall is thin and comparatively translucent. This is Cushman's *O. bartschi,* var. *plana.*

The third form is very similar to No. 2, but has all of the sutures beaded, the beads becoming smaller in successive chambers. The surface of the chambers, except in the second half of the last whorl, is covered with granules. It is therefore identical with *O. bartschi,* var. *ornata* Cushman.

All of the examples of *Operculina* present in a quantity of the material were picked out. There were 44 specimens, of which 13 were of the first form, 30 of the second, and 1 of the third. Sections made show that the first is the megalospheric and the second the microspheric. The third was not sectioned, as it was represented by only one specimen, but it is megalospheric. It should be noted that the microspheric form is always smaller than the megalospheric and is more than twice as common.

The proloculus of the first form attains an internal diameter of 0.231 mm., which is much larger than the maximum diameter given by Hofker, viz., 0.060 mm. The diameter of the proloculus of two sections of the microspheric form is respectively 0.061 (external) and 0.039 (internal) and 0.056 (external) and 0.035 (internal). Hofker gives the diameter of the proloculus of the microspheric form as 0.027 mm.

## Genus **Operculinella** Yabe, 1918.

### Operculinella venosa (Fichtel and Moll).

(Plate XVII., figs. 21, 22, text-fig. 7.)

*Nautilus venosus* Fichtel and Moll, 1798, p. 59, pl. viii., figs. *e-h.*
*Amphistegina cumingii* Carpenter, 1859, p. 32, pl. v., figs. 13-17.
*Nummulina radiata* Carpenter (*non Nautilus radiatus* Fichtel and Moll), 1862, p. 275.
*Nummulites cumingii* (Carp.): Brady, 1884, p. 749 pl. cxii., figs. 11-13; text-fig. 22.
*Operculinella cumingii* (Carp.): Yabe, 1918, p. 122, pl. xvii., figs. 8-12.
*Operculina venosa* (F. & M.); Hofker, 1933, p. 143, pl. v., figs. 13-16; text-fig. 32*a-c.*

The structure of this species has been fully described by Carpenter and by Hofker. The latter has found it to be trimorphic, the outspread type of shell being the microspheric form.

In the material we have examined, *O. venosa* is very rare, the only records being from:—

Recent—Thursday Island; Shark Bay, Western Australia, 8 fms.

Late Tertiary—Yule Island, Papua.

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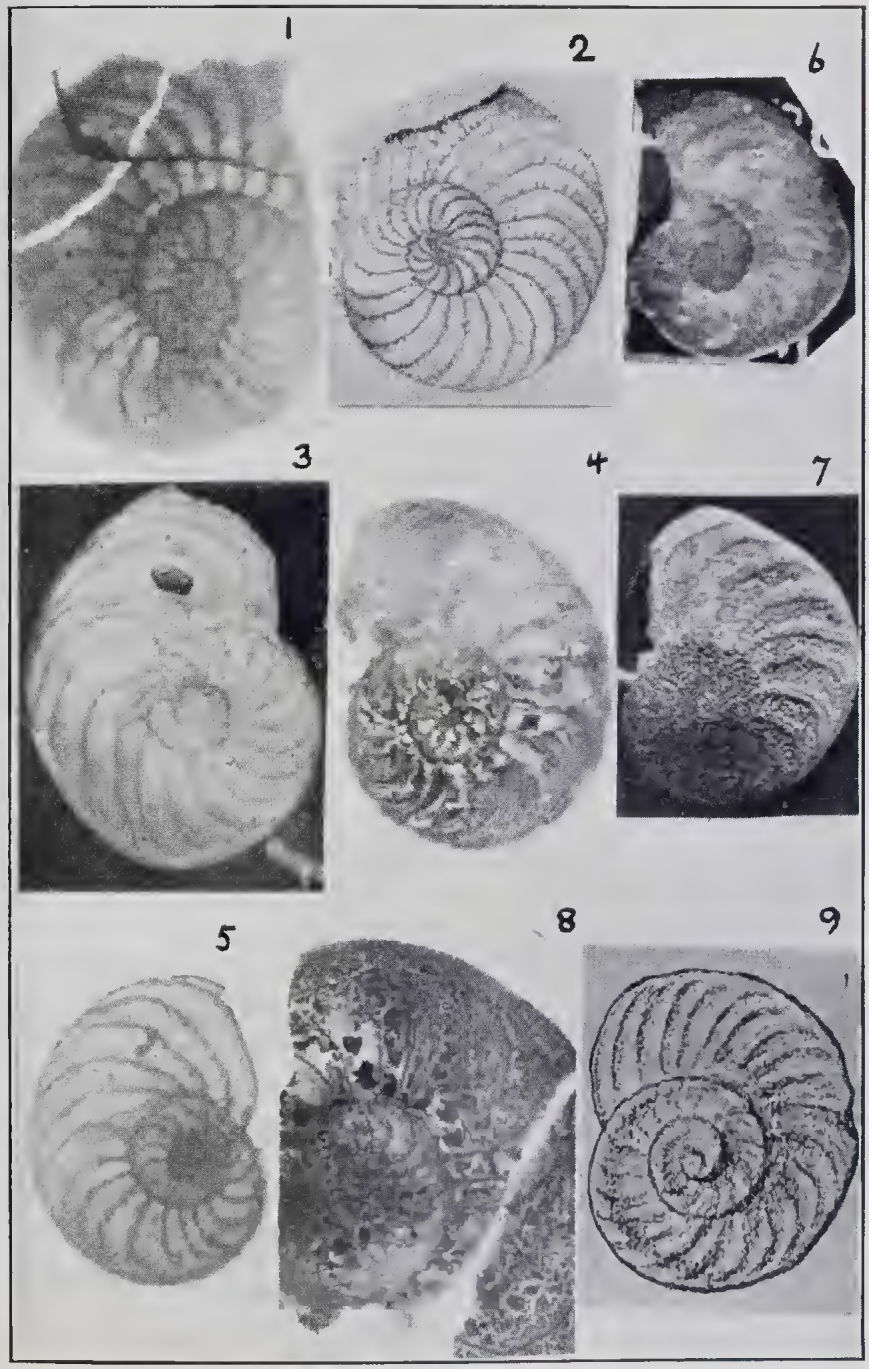


*F. C. photo*].

**Operculina complanata, O. victoriensis, O. kawakawaensis.**

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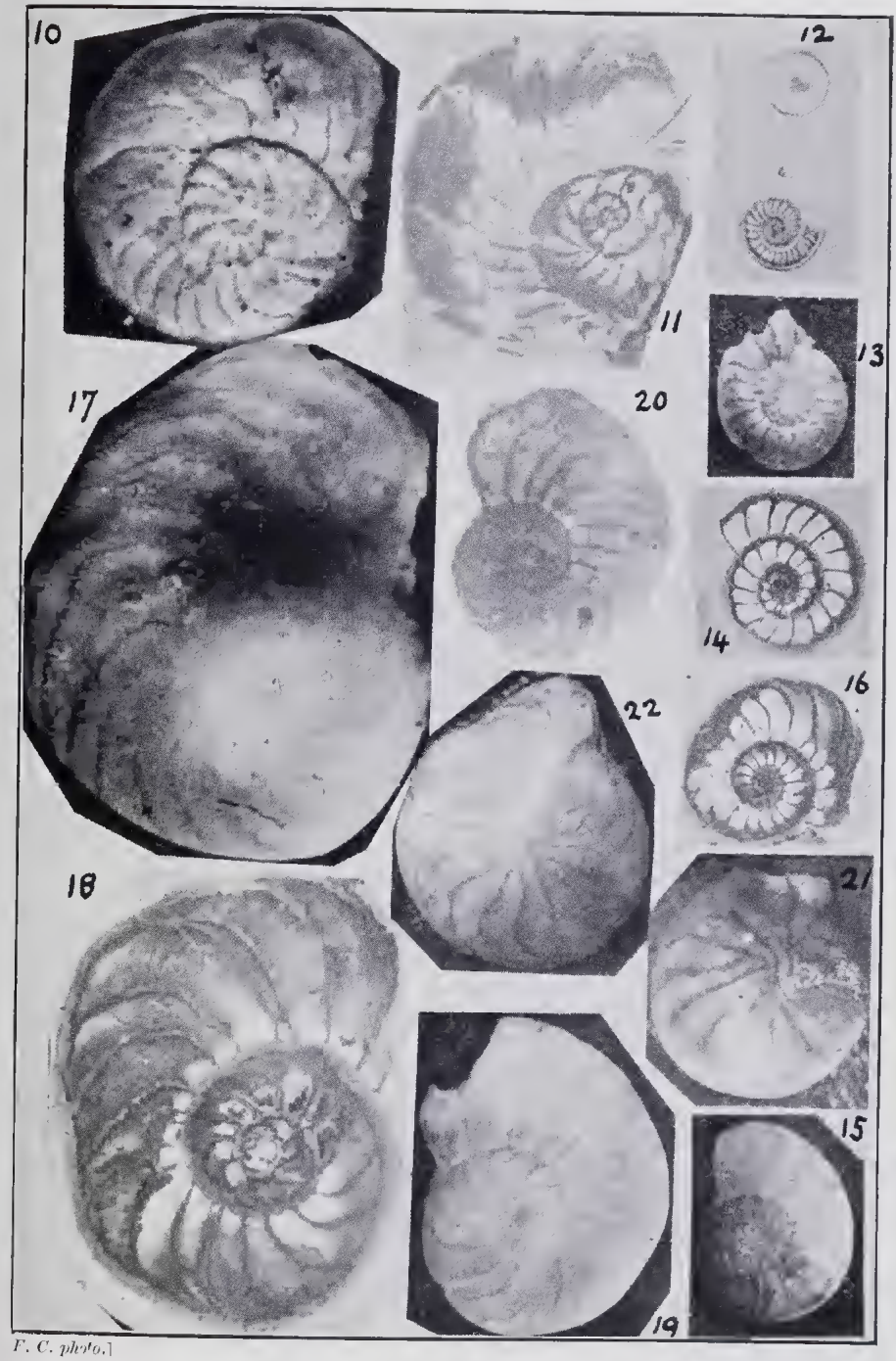


*F. C. photo.*]

Operculina matapauensis, O. ammonoides, O. bartschi and Operculinella venosa.

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## Explanation of Plates.

PLATE XVI.

FIG. 1.—*Operculina complanata* (Defrance). Lower Miocene (Aquitanian). Dax, near Bordeaux, S. of France. × 14.

FIG. 2.—*O. complanata*. Horizontal section. Lower Miocene. Lagus, S. of France. × 7.

FIG. 3.—*Operculina victoriensis*, sp. nov. Holotype. Form A. Lower Miocene. Red Bluff, Shelford, Victoria. × 14.

FIG. 4.—*O. victoriensis*, sp. nov. Form A2. Horizontal section. Lower Miocene. Red Bluff, Shelford. × 14.

FIG. 5.—*O. victoriensis*, sp. nov. Form A1. Horizontal section. Lower Miocene. Red Bluff, Shelford. × 14.

FIG. 6.—*O. victoriensis*, sp. nov. Paratype. Form B. Lower Miocene. Altona Bay Coal Shaft, Port Phillip. × 7.

FIG. 7.—*O. victoriensis*, sp. nov. Paratype. Form B. Lower Miocene. Hamilton Bore, 80-88 feet, Western Victoria. × 14.

FIG. 8.—*O. victoriensis*, sp. nov. Form B (smooth shelled). Horizontal section. Lower Miocene. Altona Bay Coal Shaft. × 14.

FIG. 9.—*Operculina kawakawaensis*, sp. nov. Copied from original drawing. Lower Miocene. Kawakawa, Bay of Islands, N. Zealand.

PLATE XVII.

FIG. 10.—*Operculina matapauensis*, sp. nov. Holotype. Lower Mid-Miocene (stage f.). Matapau, New Guinea. × 14.

FIG. 11.—*O. matapauensis*, sp. nov. Horizontal section. Lower Mid-Miocene. Matapau, New Guinea. × 14.

FIG. 12.—*Operculina ammonoides* (Gronovius). Original figure of "Nautilus ammonoides", Gronovius, 1781.

FIG. 13.—*O. ammonoides* (Gronovius). Plesiotype. Recent. Great Barrier Reef, near Townsville, Queensland. × 14.

FIG. 14.—*O. ammonoides* (Gron.). Form B. Horizontal section. Great Barrier Reef, near Townsville, Queensland. × 14.

FIG. 15.—*O. ammonoides* (Gron.). Plesiotype, forma *O. gaimardi* d'Orb. Same locality. × 14.

FIG. 16.—*O. ammonoides* (Gron.). Form B (forma *O. gaimardi* d'Orb.). Horizontal section. Same locality. × 14.

FIG. 17.—*Operculina bartschi* Cushman. Form A. Recent. Off Masthead Island, Queensland, 20 fathoms. × 14.

FIG. 18.—*O. bartschi* Cushman. Form A. Horizontal section. Same locality. × 14.

FIG. 19.—*O. bartschi* Cushm. Form B. Same locality. × 14.

FIG. 20.—*O. bartschi* Cushm. Form B (= *O. bartschi*, var. *plana* Cushman). Horizontal section. Same locality. × 14.

FIG. 21.—*Operculinella venosa* (Fichtel and Moll). Form A. Shark Bay, W. Australia, 8 fathoms. × 14.

FIG. 22.—*O. venosa* (F. and M.). Form B. Same locality. × 14.